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# Science Data Validation Plan

## Summary Charts

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January 12, 2000

- **Measurement and science objectives**

The purpose of the MISR experiment is to acquire systematic multi-angle imagery for global monitoring over a multi-year period of top-of-atmosphere and surface albedos and to measure the shortwave radiative properties of aerosols, clouds, and surface scenes. These data will be used to characterize radiative impact of aerosols, surface albedo and cloud field albedo on the Earth's climate. More specifically, as an example, these data can be used for modeling of atmospheric temperature perturbations due to radiative forcing.

- **Mission**

The instrument launched on the first Earth Observing System (EOS) spacecraft (Terra/EOS-AM1) on December 18, 1999 from Vandenberg AFB, California. Please see MISR home page (<http://www-misr.jpl.nasa.gov>) for updates of MISR progress. Nominal mission is six years in duration.

- **Science data products**

- **Aerosol/Surface**

- (1) column aerosol optical depths, compositional model identifiers, and retrieval residuals
- (2) tropospheric aerosol optical depth upper bound and band-differenced optical depth
- (3) hemispherical directional reflectance factor (HDRF), bidirectional reflectance factor (BRF), BRF model parameters
- (4) bihemispherical reflectance (BHR), directional hemispherical reflectance (DHR) (spectral and PAR-integrated)
- (5) scene classifiers, leaf area index (LAI), and fractional absorbed photosynthetically active radiation (FPAR)
- (6) water leaving equivalent reflectance
- (7) phytoplankton pigment concentration

- TOA/Cloud

- (1) radiometric, stereoscopic, and angular signature cloud masks
- (2) stereoscopic heights, winds, and Reflecting Level Reference Altitude (RLRA)
- (3) parameters referenced to the RLRA including bidirectional reflectance factors, local albedos, view obscuration information, and texture indices
- (4) regional scene classifiers, cloud and topographic shadow masks
- (5) coarse resolution restrictive and expansive TOA cloud and cloud field albedos

- **Overall approach**

- Aerosol

Two approaches to aerosol algorithm and product validation are used: (1) field experiments of short duration at specific sites that seek to isolate aerosols of given characteristics cast against chosen surface reflectance backgrounds, and (2) long-term comparisons of ensemble averages of aerosol optical depth and properties gathered at permanent maintained installations instrumented to make measurements automatically over time of direct solar irradiance, and spectral global irradiance. The intercomparisons (2) will carry the statistical strength of large numbers of observations from both ground-based and MISR-derived pathways developed in observational time series.

- Surface

The sphere-scanning radiometer PARABOLA III (JPL instrument) measurements are taken as the standard basis for judgment of MISR BRF retrieval, for the calculation of HDRF and BHR, and for the validation of such quantities as obtained from MISR. The simplest strategy is direct comparison between the BRF/HDRF derived from the multi-angle measurements of AirMISR for a site with surface and sky radiance measurements of the same site supplied by PARABOLA III. The BRF is obtained from AirMISR and MISR measurements by the use of parameterized BRF models. The for simple homogeneous areas of land surface, the BRF is obtained from PARABOLA III data by solution of the fundamental integral equation describing reflection of diffuse and direct incident light at the surface. For inhomogeneous terrain at the scale of the measurements, a parametric model (few parameters) will be used together with chi-square criterion of fit to choose the best model

- TOA/Cloud

MISR cloud validation objectives will be achieved through three main approaches: (1) EOS-AM1 Instrument Assessments - comparison and analysis of common cloud products, such as cloud masks, between MODIS, CERES, ASTER and MISR; (2) Long-term Assessments - analysis obtained by way of comparisons with long term measurements at fixed sites. These comparisons will be, at least partially, statistical in nature and are expected to test algorithms under a robust set of conditions; and (3) Short-term Assessments - analysis via comparisons with independent observations obtained as part of specific field campaigns. These comparisons, which are essentially case studies, will be conducted for two reasons. First, they can be conducted at locations not used in longer term assessments and hence broaden the range of climatic conditions. However, their primary purpose is to augment the long-term activities by providing periods with a more complete, and hopefully more redundant, data set, in essence enabling us to gain a better understanding of the accuracy and limitations of the independent data sources.

- **Sampling requirements and trade-offs**

- **Aerosol**

Long term measurement of aerosol optical depth and aerosol model are carried out continuously at about fifteen minute intervals with the CIMEL solar radiometer compatible with AERONET measurements in general. At local MISR ground validation sites, measurements are carried out at 10 sec to up to 15 minute intervals depending upon whether aerosol optical depth or aerosol model retrievals are sought. The local MISR pixel size retrievals can be compared with seven minute records available from ground stations. Extensions of surface observations to the ~ 17.6 km scale reported by MISR are only possible approximately at present. These are made by averaging in time the time series aerosol optical depths of individual stations or by use of interpolation on network observations where these are available. AirMISR will also be used in a stair-step retrieval scheme between ground and MISR for large-scale comparisons. In this case the comparisons will be between MISR algorithms from AirMISR retrievals and MISR algorithms from MISR retrievals.

- **Surface**

The surface BRF is derived locally at ~100 m scale from PARABOLA measurements and used to validate locally the BRF retrievals supplied by AirMISR. Extension of the observations to the ~1.1 km scale is supplied by additional AirMISR retrievals for scales up to ~10 km. The chain is thus PARABOLA scale -> local AirMISR scale -> MISR scale.

Temporal sampling of BRF variability is more problematical, as automated networks such as AERONET employing PARABOLA measurements for systematic unattended BRF retrieval, do not presently exist. The plan is to select a few sites representing major biome types for temporal periodic BRF retrieval to capture interseasonal and intraseasonal variability. The actual sites are under study. Some may correspond to EOS core validation sites, and some to MISR specific needs.

- **TOA/Cloud**

The EOS-AM1 platform will complete its orbital cycle once every 16 days. During this period every part of the Earth is imaged, but not equally. Regions near the poles are observed more frequently than those regions near the equator. For example, Barrow, Alaska (one of the ARM sites) will be imaged 6 times every 16 days, while Nauru Island (another ARM site) in the tropical western Pacific will be imaged 2 times every 16 days. Given the sporadic nature of cloud coverage, several years of data will have to be collected before the long term assessments activities can be completed. During the early stages, the validation efforts will focus more strongly on the EOS-AM1 instrument and short-term assessment activities.

- **Measures of success**

- **Aerosol/Surface**

Successful validation of a MISR algorithm (and products derived therefrom) here implies that the following criteria be met:

- (1) Agreement of values (aerosol optical depths, microphysical properties, HDRF, BRF, HDR, BHR) derived or assumed by MISR and derived by ground-based pathways, to within expected errors for each pathway.
- (2) For aerosol and surface properties, radiance closure to within expected errors of the MISR and ground-based pathways. Radiance closure here means that the aerosol model, surface BRF, and optical depths retrieved by the ground-based pathway, generate, using the adopted radiative transfer code, surface downwelling and near TOA or TOA upwelling radiances, together with surface irradiances, that agree with surface observations and with measurements from AirMISR and MISR. For ground-based path this criterion should be automatically satisfied since the surface measurements are used to derive the aerosol model in the first place.

- **TOA/Cloud**

Ultimately, MISR cloud products will be considered valid, or a success, if they produces results which are accurate and consistent in both the long term and short term with measurements from independent data sources. This not only means that any given MISR-based results should fall within some precision of an independent measurement, but also that the various data sources should yield parameters with similar statistical properties. Situations which produce dissimilar results will be carefully studied to isolate the cause and determine if the problem is an inherent limitation in one of the data sources or if corrective action can be taken.

- Near-term post launch field experiments using AirMISR**

## Early 2000 Science Flights

SITE-DATE	EXPERIMENT TYPE	AEROSOL TYPE	BOUNDARY CONDITION	AIRBORNE INSTRUMENT	STATUS
Lunar Lake, NV Launch + 60 days	Vicarious calibration of MISR. Simultaneous overflight of site with AirMISR	ambient	homogeneous dry playa	AirMISR, RC-10	Planned
Lake Mendota, WI 2/17-2/23	Snow/Ice BRF from PARABOLA III and AirMISR	ambient	Lake Ice with possible snow cover	AirMISR, RC-10	Planned
ARM/CART 2/17-3/7	Cloud BRF, stereo height, downwelling radiance from cloud bottoms with PARABOLA III	ambient	heterogeneous croplands, fallow fields, possible snow cover	AirMISR, RC-10	Planned
SAFARI-2000, August - September	Comparison of surface, AirMISR, MISR retrievals of BRF and aerosols over African savannas and pans. Calibration of MISR using Etosha Pan	ambient, probably including smoke from savannah burning plus industrial pollutants	Heterogeneous surfaces savannah, forest	AirMISR, RC-10, MAS	Planned

- **Operational surface networks and special sites**

- Aerosol/Surface

Achievement of the long term global product validation goals of MISR depends upon the existence of networks and special sites that provide continuous well-calibrated surface and other atmospheric observations relevant to MISR's products, and upon special sites that offer unique infrastructure to study surface cover. Two radiation networks, AERONET and ISIS, the ARM CART site, EOS core validation sites, once these are established, the BOREAS experiment site, and other special vegetation sites to be chosen. The BOREAS SSA experiment area was used previously for a MISR algorithm validation experiment over canopies of needle forest and aspen, before the AirMISR era (e.g., ASAS). In future, experiments at Monterey (marine aerosol and ocean waters), Lake Tahoe (ambient aerosol over lake waters), Canopy Crane (old growth forest), Potlatch (Poplar tree farm) are planned

- TOA/Cloud

The primary ground-based remote sensing sites used in support of MISR validation will be the Department of Energy Atmospheric Radiation Measurement program sites. The development and testing of algorithms to ingest and analyze data from the ARM sites is being developed. Important aspects of the ground-based validation effort (such as how compare narrow field of view radar measurements with larger satellite views) are being studied.

- **Field studies and EOS-targeted coordinated field campaigns**

- Aerosol/Surface

Post-launch field campaigns are planned with other EOS groups. Focus of field experiments will continue to be algorithm as well as geophysical product validation. Field experiments in cooperation with University of Arizona as well as other interested domestic and foreign groups will focus on periodic vicarious calibration of MISR and MODIS using desert lake bed sites. BRF retrieval experiments on vegetation canopies are planned for sites mentioned previously, and some in conjunction with the MODIS MOD-LAND validation team. BRF experiments, covering an array of surface cover types, will also be carried out. These may or may not have AirMISR overflights in accompaniment, but in any case include PARABOLA III and atmospheric measurements, and in coordination with Terra platform (MISR) overpasses.



- TOA/Cloud

Because of the variable types and quality of data that are available from preexisting ground-based sites, more intensive short-term assessment activities, where airborne measurements can be incorporated, will remain important in the post-launch validation effort. Data will be gathered and analyzed from non-EOS missions, such as the yearly intensive operational periods (IOPs) held by the ARM Clouds Working Group.

The MISR science team will also take advantage of field measurements conducted by other EOS validation science teams. In terms of cloud products this includes plans by the MODIS team to conduct field campaigns targeted at:

- (1) cirrus cloud near Hawaii and in the Gulf of Mexico (2000);
- (2) marine stratocumulus clouds and valley fog in California (2000).

The sites and timing for some MISR organized short-term validation activities will be identified in the future based on detected problems, that is, situations where MISR-based retrievals do not agree with those from other instruments. At this time, the MISR validation team anticipates conducting the following post-launch targeted exercises, but recognize that more or different needs may be identified in the future:

- (1) Cumulus / broken cloud fields - Spring or Summer 2000;
- (2) Single layered cirrus clouds and cirrus clouds over lower cloud fields - late 2000 or Spring 2001;
- (3) Continental stratus clouds over heterogeneous terrain - Coordinated with ARM Clouds Working Group - late 1999 or 2000.

- **Correlations with other platform instrument results, other satellite data**

Common data products between MISR and other EOS-AM1 instruments (ASTER, CERES, and MODIS) will be compared. These data sources are collected continuously and simultaneously over the same locations. MISR stereo-derived cloud tops will be compared with IR retrievals from ESA (European Space Agency) satellites (primarily ATSR). An intercomparison campaign in planning is SAFARI 2000. See section below for AirMISR and MISR expected roles.

- **Measurement needs (in situ) at calibration/validation sites**

- **Aerosol/Surface**

A full suite of surface spectral radiance (upwelling and downwelling) and irradiance measurements together with observations of multiangle upwelling radiances by AirMISR are ordinarily sought at each local measurement site where AirMISR participates. These ground-based data are used to define an aerosol scattering model (column-effective single scattering albedo and phase function -> size and composition), the surface BRF and spectral HDRF at normal incidence, and to validation of the aerosol model through radiance closure. Instrumentation includes sunphotometers (Reagan), diffuse/direct irradiance monitors (MFRSR, CIMEL), surface reflectance spectrometers (ASD), and a conical-scanning bidirectional reflectance spectroradiometer (PARABOLA III). In addition, weather data, radiosonde observations, and all-sky (fisheye lens) camera data supplement characterization of the site and observing conditions for the time of platform overpass.

- **TOA/Cloud**

The ARM sites are the primary validation sites which will be used by in the MISR cloud validation effort. The ARM sites include (1) the Southern Great Plains (SGP) site in Oklahoma, (2) the Tropical Western Pacific (TWP) with sites on Nauru island and at Manus Island, Papua New Guinea, and (3) the North Slope of Alaska (NSA) site at Point Barrow. All of these sites are equipped (or soon will be) with vertically pointing millimeter cloud radars, as well as lidars which can be used to detect clouds and determine their vertical structure, including cloud top height. The ARM sites are equipped with hemispherical viewing instrumentation, e.g., whole sky imagers, which can be used to infer the spatial cloud fraction. Finally, these sites have routine rawinsonde releases (and in the case of the SGP a radar wind profiler) which will be used to examine cloud velocity retrievals.

- The MISR aircraft platform simulator AirMISR

The MISR simulator AirMISR has been developed and is currently operational. AirMISR simulates the multiangle and spectral observational characteristics of MISR itself using a single spare MISR camera mounted on a gimbal system in the nose of the ER-2 aircraft. The instrument operates on the ER-2 platform at an altitude of ~20 km above sea level (The single pixel FOV generated varies from 7 m across track x 6 m along track in the nadir view to 21 m across track x 55 m along track at the most oblique viewing angles of  $\pm 70.5^\circ$ ). AirMISR will be used for algorithm validation studies (continuing into the post launch), and as a well-calibrated radiometer for radiance-based calibration of MISR on orbit, and to aid in scaling of locally derived MISR geophysical parameters to MISR scale of retrieval and reporting. The use of a single camera obviously reduces the labor of airborne vicarious calibration under the assumption that camera calibration is independent of camera tilt in the observation plane.

Participation of AirMISR is important to the success of the MISR validation activities and in the quest for development and expansion of the multiangle observation method in atmospheric, cloud, BRF and albedo measurements. Applications to such fields as aerosol science, identification of aerosol sources, transport patterns, transformations, and deposition, ecological sciences through interpretation of the BRF for biogeochemical applications and material balance studies are anticipated.

The ground tracks of AirMISR over a chosen target involve three distinct paths and six solar azimuths. The first path coincides with the MISR ground track in azimuth and local time of the MISR overpass (expected to be around 10:30 for mid-latitude northern hemisphere targets). The second path reverses this heading and duplicates the first path. The third path lies in the principal plane of the Sun, and its reverse heading. The fifth heading bisects the first two paths, and the sixth is a reverse of the fifth. Altogether the collection of paths forms a rose like pattern. Experience shows that duplication of paths helps guarantee successful recover of angular information at all angles. Each overpass to capture all nine view angles requires a path length of 75 km each direction about the target point. Each complete overpass requires 15 minutes of flight time. A complete pattern for a single target thus requires 75 minutes + about 50 minutes additional to accomplish turn-arounds and transit between lines.

The MISR validation team anticipates having approximately 10-20 hours of ER-2 flight time per flight season and the necessary support to analyze these data each year. AirMISR resides in the nose of the ER-2, and, for example, can be flown compatibly with AVIRIS (Airborne Visible Infrared Imaging Spectrometer) MAS (MODIS Airborne Simulator), SSFR (Solar Spectral Flux Radiometer), CLS (Cloud Lidar System). The current AirMISR flight data summary can be found at <http://www-misr.jpl.nasa.gov/misr-sion/valwork/mivalres.html#airmisr>

- **Geometric registration and location**

Principal responsibility for validation of the MISR camera model, pointing of MISR on the EOS platform, location of MISR pixels at all view angles and instrument bandpasses in Level 1 data, resides with the MISR Geocal Team. The Geocal team will use LANDSAT imagery, GPS and conventional topographic maps to validate the camera model, image quality, registration, and pixel location. The MISR (Geophysical Product) Validation Team will ordinarily request geographic coordinates of unresampled MISR pixels as starting point for actual ground location in both calibration and validation sites. The supplied coordinates together with imagery of Local Mode sites at the highest image resolution, will be compared with ground areas containing targets of highly differing reflectance (e.g., areal contrast) to compare reported and (differential) GPS-derived locations. We thereby expect to verify locations to within the platform pointing uncertainty.

Local geometric registration and image location with AirMISR is accomplished using aerial photography acquired with the RC-10 aerial cameras, the image data, themselves, and 1:24000 USGS topographic maps of target areas.



- **SAFARI-2000**

The Southern African Regional Science Initiative: SAFARI 2000 is an international science initiative focussed on development of a better understanding of the southern African earth-atmosphere-human system. The goal is to integrate remote sensing, airborne sampling, ground-based studies, and computer modeling to link the biological, physical and chemical components of regional ecosystems; these are linked by the semi-closed atmospheric gyre that persists over the region. Version 1.0 of the Science Plan may be found at <http://safari.gecp.virginia.edu/>.

SAFARI-2000 will provide an occasion for cross-validation of the Terra Platform instruments and for accumulation of a continuing time series of measurements to track aerosol source-sink patterns, transport and chemical transformations, reflectance retrievals over time and tracing these changes to ecological and land-use evolution of the study regions. The August-September 2000 intensive field campaign will provide an opportunity for vicarious calibration of MISR using Etosha Pan in Namibia, and possibly other South African sites, and for local validation of MISR aerosol, surface, and cloud products. AirMISR, based in Pietersburg, S.A., will fly a series of up to a dozen science sorties to sites in the Kalahari and Miombo Transects, where intensive ground measurements by international teams are planned. Once the validity of MISR geophysical products is established, MISR observations may be combined to study regional problems in long time series (five or six years). Ground methods to be employed by the MISR validation/calibration team will be similar to those developed for detailed work at north American sites. The MISR aerosol and BRF retrievals will be accomplished using MISR multiangle algorithms. Generation of aerosol compositional types, for example, will be made through the MISR aerosol climatology. At this point we will have a better idea of how well the surface-derived and the MISR-derived aerosol models agree. Source-sink distributions may be deduced from analyses of aerosol column abundance patterns plus knowledge of the vertical wind fields acquired locally from radiosonde observations or at mesoscale by model weather analyses.

- **Approach**

- Vicarious Calibration

- (1) MISR calibration results from a process which combines multiple methodologies.
    - (2) The reconciled calibration is weighted inversely to the uncertainty in each data set.
    - (3) The uncertainty in the reconciled calibration is proportional to the differences in the results, as reported for the multiple methodologies.

- Aerosol/Surface

- (1) The differences between the aerosol/ land-surface products as measured from the in-situ data, as compared to MISR products, is used to quantify the uncertainty the MISR products.

- TOA/Cloud

- (1) The cloud validation plan will document the accuracy, limitations, and uncertainties of the MISR cloud products. To accomplish this, MISR-derived results will be compared with those obtained from independent sources.

- **Role of EOSDIS**

MISR science data validation will interact with EOSDIS through the DAACs. MISR Level 2 data products will be retrieved from the appropriate DAAC for comparison with ground and aircraft based retrievals.

- **Plans for archival of validation data**

Measurement data from all field experiments as well as the parameter retrievals, comparisons and experiments reports will be archived both at the MISR team science computing facilities and at the Langley DAAC. The principal motivation is to allow recovery of the experimental conditions and permit complete traceability as well as characterization of the measurements.

- **Publications in preparation, submitted, or in press**

- (1) Vicarious calibration: A reflectance-based experiment with AirMISR, (in press), *Remote Sensing of Environment*.
- (2) PARABOLA III: A sphere-scanning radiometer for field determination of surface bidirectional reflectance functions, validation of MISR geophysical products and MISR calibration, in preparation
- (3) A Spectralon BRF data base for MISR calibration applications (submitted) *Remote Sensing of Environment*
- (4) A theoretical study of vicarious calibration including error analyses for approximately-known aerosol scattering properties and uncertain surface bidirectional reflectance factor, in preparation
- (5) On the limits of atmospheric correction via aircraft observations or ground observations alone, in preparation
- (6) Description of algorithms, code and objectives for validation data processing (MISR Validation ATBD), in preparation
- (7) Science data validation plan (JPL D-12626, Rev C)
- (8) Ground measurements of surface bidirectional reflectance factor and hemispherical-directional reflectance factor from PARABOLA II, in preparation
- (9) Vicarious calibration of AirMISR: results using Rogers Lake, CA calibration target, in preparation.